THE USE OF CONCEPT MAPS IN THE EVALUATION OF COGNITIVE MODELS OF SCIENCE. THE PHOTOELECTRIC EFFECT.

O USO DE MAPAS CONCEITUAIS NA AVALIAÇÃO DOS MODELOS COGNITIVOS DA CIÊNCIA – O EFEITO FOTOELÉTRICO

Prof. Dr. Luiz Adolfo de Mello [ladmello@ufs.b]

Departamento de Física, Universidade Federal de Sergipe,
Cidade Universitária Prof. José Aloísio de Campos
Av. Marechal Rondon, s/n Jardim Rosa Elze - CEP 49100-000 - São Cristóvão/SE

Abstract: Using the theoretical framework of cognitive theory of science and using conceptual mapping will do the study of how original scientific models are transposed to the didactic models. This is, to analyze how the knowledge produced in the 'academic spheres' is modified, adapted, simplified and consolidate as knowledge to be taught in the classroom. Here we study the topic of physics called photoelectric effect. We will review the main concepts used by Albert Einstein (1905a) in the development of the theory of the photoelectric effect and how they were transcribed, filtered and drawn up in textbooks made for the academic course of Bachelor of Science in Physics, for the basic cycle of university course and for high school. That is, how the eight (8) chapters of his article condense in a single section in high school textbooks. We will use here Concept Map to analyze how does the didactic transposition of this theory in the generalized sense by Izquierdo-Aymerich (2003) and synthesized by de Mello (2015a) of Chevallard theory (1985). We analyze, using as a theoretical framework the cognitive science theory [Nersessian, 1992; Jhonson-Laird, 1980] as the fact of the theory for the photoelectric effect have been proposal before the paradigm of quantum mechanics have been established affected the epistemological construction of that article and how this fact was transposed to textbooks. Here we will consolidate the most current version of the theory of didactic transposition that encompasses (synthesizes) the theory of Chevallard, cognitive theory of science and mental models of Jhonson-Laird. We will confirm here that CM is for the analysis of conceptual construction of any theory the equivalent of structured language is for programming.

Key Words: Conceptual Maps, mental models, cognitive science theory, relational thinking, teacher reflections, textbook analysis.

Resumo: Através do referencial teórico da teoria cognitiva da ciência e usando Mapas Conceituais faremos o estudo de como os modelos científicos, na sua forma original, são transpostos aos modelos didáticos. Isto é, se fará a analise de como o conhecimento produzido nas 'esferas acadêmicas' se modificam, se adaptam, se simplificam e se consolidam como saberes a serem ensinados em sala de aula.

Abordaremos aqui o tópico da Física denominado Efeito Fotoelétrico. Analisaremos os conceitos principais usados por Albert Einstein (1905) no desenvolvimento da teoria do Efeito Fotoelétrico e como estes foram transcritos, filtrados e elaborados nos livros textos confeccionados para o curso profissionalizante de bacharel em Física, para o ciclo básico do curso universitário e para o ensino médio. Ou seja, como os oito (8) capítulos de seu artigo se condensam em uma única seção nos livros textos do ensino médio. Usaremos aqui Mapeamento Conceitual (CM) para analisarmos como ocorre a transposição didática desta teoria, no sentido generalizado por Izquierdo-Aymerich (2003) e sintetizado por de Mello (2015a) da teoria de Chevallard (1991). Analisaremos, usando como referencial teórico a Teoria cognitiva da Ciência [Nersessian, 1992; Jhonson-Laird, 1980], como o fato da teoria para o Efeito Fotoelétrico ter sido proposta antes que o paradigma da Mecânica Quântica ter sido estabelecido afetou a construção epistemológica desse artigo e como este fato foi transposto aos livros didáticos. Consolidaremos aqui a versão mais atual da teoria da transposição didática que engloba (sintetiza) a teoria de Chevallard, a teoria cognitiva da ciência e modelos mentais de Jhonson-Laird. Confirmaremos aqui que CM são para a análise da construção conceitual de qualquer teoria o equivalente da linguagem estruturada é para a programação.

Palavras Chaves: Mapas Conceituais, Modelos Mentais, Teoria Cognitiva da Ciência, Transposição Didática.

Introduction

Recent contributions from the epistemology of science for the teaching of Sciences have originated a new approach (Theory) for this last one called "cognitive model of science" (CTS). That originates from the Kuhnian philosophy of science (Kuhn, 1970). Along with other recent contribution to theories for the teaching of the sciences, the theory of "didactic transposition", that comes from new scientific education (Chevallard, 1985), suggest the possibility of examining with much more depth as the knowledge produced in the scientific spheres are translated at school sphere [Izquierdo, 2003]. The use of CM allows establish "well defined rules" to make the analysis of how scientific concepts are developed, organized and built in the development of theories and laws of science, in particularly to physics [de Mello, 2015a]. That is, CM is a very powerful tool in the study of didactic transposition. This allows you to build a form of algorithmic language to perform this analysis [de Mello, 2015b]. Thus, when we propose to make a DT the first question that arises is: what is it ‘do science’ and what is teach science?

The Merriam-Webster Online Dictionary defines:

> Science (Scientia the Latin, translated as "knowledge") refers to any known or systematic practice. In the strict sense, science refers to the system of acquiring knowledge based on the scientific method and to the organized body of knowledge achieved through such research. [Merrian, 2015].

Thus, we have that to teach science we must teach systems or methods to acquire knowledge and, at the same time, teach how to reach this body organized knowledge from these. But, this is, in general, impossible to reproduce in the classroom [Izqueirdo-Aymerich, 2005]. Thus, the question arises: what is teach science in the classroom of middle school education as the superior?

If we analyze the textbooks written for the middle school, from the point of view of knowledge and of his method of obtaining, we will see that these are classified into two types: (a) those that start exposing the theory and then presenting the experimental facts that redounded in their formulation or discovery as merely a confirmation of its validity or importance; b) and those who start exposing the experimental facts that redounded in its formulation and putting the theory as a direct consequence of these facts. With the introduction of modern teaching methodologies we have some alternative versions of exposure of textbooks. We have textbooks written under the methodology of based learning problems (Glencoe, 2005) in which each topic is preceded and motivated by a presentation of an enigma that contextualizes the necessity of searching or formulation of the theory.

Thus, within the context of editorial or public policies, and from the national programs of production of textbooks is of vital importance to know how the scientific knowledge is transposed to textbooks and how this is effectively taught in the classroom. The scientific theory that addresses this problem is called Didactic Transposition.

Didactic Transposition

Didactic transposition (DT) is the theory that analyzes how the scientific knowledge is transposed or rewritten in a pedagogical way for textbooks [Chevallard, 1991]. According Pietrocolla [Brockington, 2005], he defines the didactic transposition as a efficient theory to analyze the processes through which the scientific knowledge produced by scientists (the scholarly knowledge) becomes that which is contained in the programs and textbooks (the Knowledge to be Taught) and mainly in what actually appears in classrooms (the Knowledge Taught). At first glance it seems that the knowledge to be taught is a merely simplification of the scholarly knowledge. This is, somewhat different from those present in the laboratories and research groups [Brockington, 2005].

After Chevallard to understand deeply how scientific knowledge is transcribed to the textbooks we have to include in this analysis the external environment in which this occurs. This transformation occurs within an environment or within a University Sphere (the Didactic System) that lies within a small universe that is the external environment (the Education System)[1]. That is, we must take into account that there are factors outside the school system, inserted in the wider environment, where all three spheres coexist and influence [Brockington, 2005].

Chevallard uses the word noosphere to designate and encompass the elements participants that regulating the selection and that determine the modifications that

[1] This is entirely true in the USA and in Europe. But, for example in Brazil, this is not entirely true.

the scholarly knowledge should suffer to transform in Knowledge Taught. The noosphere is composed, in general, by scientists, educators, teachers, politicians, authors of textbooks, among others [Brockington, 2005].

The ideas and concepts developed by Chevallard [Chevallard, 1991] were developed in the study of the passage of the "knowledge" of the research environment for the middle school. In this model of didactic transposition he defines or makes the simplification that the research environment is unique. Or that the knowledge produced in the research environment is already produced in the final form to be transposed directly (consumed) for middle school. But, de Mello [2015a] showed that the theory of DT can be applied to the structure of the higher education, and that the transformation of scholarly knowledge begins in this sphere of knowledge (or Epistemosphere). With the spread of courses and graduate programs it was created another substrates between the knowledge produced in research spheres and the basic university education. We now have five levels of presentation or transcription of knowledge. The level: 1) Research; 2) Postgraduate; 3) Academic; 4) Basic graduation and finally 5) high school.

We will confirm here, for the case of a specific topic of Physics, which DT occurs in cascade from research environment for the environment of university education, and from this to the didactic system of middle school.

As said above (Mello, 2015a) with the expansion of the editorial market we have currently a relative variety of textbooks produced within this epistemosphere. This created the possibility and the need to produce new proposals of teaching. This production has generated a certain amount of text books with specific characteristics and objectives.

Didactic Transposition and the Cognitive Model of Science

On the other hand, for understanding the DT we must understand what is the academic scientific knowledge and the scholar knowledge. I have already explained above what is meant by science. But we do not enter into the details of the vision or modern conception of what is a scientific theory or scientific knowledge. Let us start by defining what scientific knowledge is, or in the language of Chevallard, the Knowledge to be Taught.

According to Izquierdo-Aymerich (2003)[2] when we simplify or define, with didactic purposes, what is science or to do science we can describe it as a way of thinking and acting in order to interpret certain phenomena and to intervene through a series of theoretical and practical structured knowledge. As a result of science education is desirable that students understand that the natural world has certain characteristics that can be modeled theoretically. Because of this we present to them, making a DT, some reconstructed facts, theoretical models, arguments and propositions that were previously selected.

[2] The following two paragraphs are a collection of statements that together form the definition of that is the DT from the CTS point of view.

How to show previously [de Mello, 2015], in most cases the theoretical models, or scientific models are adapted and / or modified for the level of understanding of students. And over time these models will be perpetuated so that teachers teach the DT of the science as this was the truth. Scientists propose theories, conceptual models and methods to formulate their explanatory purposes. But reproduce it within the context of a classroom is not entirely possible [Izquierdo-Aymerich, 2003].

In addition, if the teaching of sciences is done in accordance with the principles of meaningful learning (Ausubel, 1977), that is, a well executed didactic transposition (Chevallard, 1990), the teachers will be involved in the task of connect scientific models to used by pupils themselves, using analogies and metaphors that may help them to move from the last for the first (Duit, 1991; Flick, 1991; Ingham, 1991; Clement, 1993).

Currently, we have several university courses with various pedagogical proposals. Some proposes to train scientists in general and others to form professionals for the labour market. A group of educators advocate that the teaching of sciences should in some way reflect what is the scientific activity and to do sciences. Already others argue that science should be taught in an objective manner. That is, you should teach their concepts, theories and applications without worry about what is do science. So, the teaching of science in school cannot be based strictly on the analogy of the student as a future scientist, that is, with a strong scientific basis [ ].

In the first line Aduriz-Bravo and Izquierdo-Aymerich (2003) distinguishes between the characteristics of the two sciences, the science of scientists and that they call the science of the school. They argue that both sciences have a common cognitive objective: to understand the world and communicate theoretical ideas with precision and significantly. In addition, they propose that the didactic transposition process is to recreate the science of scientists in classrooms, according to their own values, institutional conditions, rhetoric tools and educational objectives, to convert it into a science of school.

Mental Models

But what would be these models used by the students? Without going into detail on the various forms or types of reasoning, we have that Johnson-Laird (1983, p 163) advocates that people think through mental models. Mental models, analogically to models of architecture, are as cognitive building blocks that can be combined and recombined as needed. As any other models they represent accurately or not the object or situation itself. One of its most important features is that its structure is similar (analog) to this situation or object [Hampson and Morris, 1996, apud Moreira].

Analogue models are often used to do research, create, test and communicate ideas (Bent, 1984; Black, 1962; apud Harrison, 2000). The analogy is an effective way to explain new ideas provided that the tutor and the listener to understand the analogy in the same way. The analogy is called the familiar object, experience or process [Gentner, 2001]. Analog explanations work when the tutor and the listener agree with analog mappings that exist between the analog (prior knowledge) and the target (scientific knowledge). And we say that the mappings are shared when both parties agree that the analog is similar to target in this or that way.

In other words, mental model is an internal representation of information that corresponds, similarly, to the state of things that is being represented, whatever it. Mental models are structural analogues of the world [Moreira, 1996].

As an example we have the atomic model. Depending on the level of education if we ask what would be the atomic model we would have a different answer. The model of Thompson, or of Bohr's or the quantum mechanics model. Thus, there is not a single mental model for a given state of things. On the contrary, there can be multiple models, even if only one of them represents in an optimally way this state of affairs. Each mental model is a representation of that state of things analog and reciprocally, each analog representation corresponds to a mental model [Moreira, 1996].

But, there is a basic difference between conceptual models and mental models (Norman, 1983). The physical models are conceptual models, that is, models built by researchers to be able to draw up their theories and eventually facilitate the understanding or the teaching of physical systems. They are accurate, consistent and complete representations of physical phenomena according to a certain theory [Moreira, 2002]. However, the students' models, or any individual, including those that create conceptual models, are mental models, that is models that people build to represent the states of physical things (as well as the states of abstract things) through their ordinary experiences. [Johnson-Laird,1983; Moreira, 1996; Greca, 2002].

In this article we will investigate how the scientific knowledge produced within a historical context of an epistemological or scientific revolution, in the sense of Kuhn (1970), is transcribed, or in the language of this article, suffers a DT for the textbooks in general. The central point of this article is to analyze, through CM, as the explanatory (scientific) models will be transforming as are transcribed for each epoch or paradigm and for each level of understanding.

But the current view what is a scientific theory or scientific knowledge is very advanced. Thus, it is necessary a little revision of theoretical parameters that we use here to do this study. In particular we will use the theoretical frame of Cognitive Theory of Science (CTS).

A Cognitive Model of Science

The current point of view on the epistemology of science, the objective of scientific theories is not attain the truth, but to give meaning to the world, in accordance with the ultimate goal of an active transformation of nature (Hacking, 1983). The theories are the most important entities in science; they are built and modified in order to interpret the world (Duschl, 1990; apud Izquierdo-Aymerich, 2003). So, the objective of the Cognitive Theory of Science (CTS) is to understand how the scientists work and communicate (especially by means of writing), focusing its study on the semantic aspect of theories.

In order to illustrate and parameterize this problem we will have recourse to the history of science. To Boltzmann all theory is nothing more than a picture or representation of natural phenomena. For him (Boltzmann, 1890) an image or representation is a mental or subjective construction. For him a representation is an explanation of what occurs in nature. The task or objective of a theory must be the construction of a pure image of the external world, and this image is inherent to the man, this being a subjective and mental image. This image must be the star guide (Leitstern) of our thoughts and experiences. According Boltzmann theories do not have the ability to represent the essences that constitute the nature, or still, the physical reality. The scientist does not have any means to fully distinguish the image it produces from the image outside world.

From the moment that he sets theory as a representation, he refuses to discuss the atomism from arguments related to the existence, sufficient or not, of empirical data able to confirm the reality of atoms. While theory this is a picture. Thus, to evaluate it, we need to focus the discussion about its capacity to contribute to the work of construction of images of the external world, that is, of new theories (Videira, 2005 and 2006).

On the other hand, Ernst Mach and Ostwald (philosophers of nature and positivists) was opposed to the gases kinetics theory and the thermodynamics of Boltzmann stating that if the physics would be a science based and founded on natural facts, which meant the imaginary balls (atoms) created by some physicists to build the theories of atoms. Despite the epistemological differences between both, Mach and Ostwald sought to introduce in Natural Sciences fundamentally the same phenomenalist conception. For them, the physical theories have as objective to describe what is perceived by the human sensory organs, organizing what is "harvested" by these into a coherent whole and economical. In this work of organization, the human intellectual faculty is passive. Everything that is important for a good achievement of the scientific task is supplied by the observation [Videira, 2005 and 2006].

For Mach, the theory would have carried out their task if you have managed to describe what is given by the observation, without the need of being introduced into fictitious elements or hypothetical. The primacy given to empirical facts on the theory that obeys it, makes a technical element nothing more than a copy of the experience [Videira, 2005 and 2006].

It is used here a very similar design to Boltzmann's what is meant by science and what is to do science. In accordance with Carey (1992) and Nersessian (1992), the models are a type of mental representation. Hesse (1963) affirms that the scientific models allow a theory be predictive. The interpretation of a fact can be a consequence of this be related to similar or analogous facts that fit into a model. The propositional language that defines a theory is not used to describe the world, but is the construction of a mental model of it, which is a structural analogue of the real situation. So, this model is built according to strict rules and governed by existing scientific paradigm, as demonstrated in de Mello (2015b). Thus, the initial model thus generated will develop as explained other known or new phenomena.

Scientific theories are presented in textbooks as a set of models related to some facts and some identifiable instruments that give meaning to the theory. The relations between the models and the facts are developed through postulates and theoretical hypotheses, which can be more or less true or false, since that possess empirical content. A scientific theory is a family of models which in conjunction with hypotheses and or postulates establish the likeness of these models with the experimental facts. Thus, the theory necessarily contain your applications, or domain, and can be understood in part as the world interpreted (Giere, 1988; Suppe, 1989 apud Izquierdo, 2003).

These explanations, that is, theoretical ideas about the world created to understand it, are structured around concepts. For Latour (1999), these concepts, or what he calls knot or links, are those things that can help us understand the scientific activity and without which the scientific activity simply not exist [Izquierdo, 1999]. Thus, it is argued here that conceptual mapping is the ideal tool for doing this study.

Conceptual Maps

Several authors [Novak,1990 and 2006; Moreira, 2010 and 2006; Gilmar da Silva, 2007; and references] advocate the use of conceptual Maps (CM) as potentially useful instruments in education, in the evaluation of learning, in the analysis of the curriculum content and in the analysis of DT (De Mello, 2015a).

We can build Conceptual Maps to graphically represent an entire discipline, a subdiscipline, a specific topic of a discipline and so on.

Joseph D. Novak (2006) defines in a wide manner which is conceptual maps (CM):

> "Concept maps are graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts. Words on the line, referred to as linking words or linking phrases, specify the relationship between the two concepts."

When the CM is well constructed allows the visualization and perception of how the keys concepts from a particular topic or field of knowledge follow one another, intertwine and organizes themselves in the structuring of this knowledge. Thus, we tried to create some basic rules for the construction and standardization of CM's that can be seen in many articles [Novak 2006; Moreira, 2006; de Mello, 2014].

Despite these rules conceptual mapping is a very flexible tool and can be used in various ways. As stated by own Moreira (2006):

> "There are no general rules fixed for the preparation of conceptual mapping. The important thing is that the map is to be an instrument capable of demonstrating meanings attributed to concepts and relations between concepts in the context of a body of knowledge, a discipline, a matter of education."

When used as evaluation tool flexibility in building CM is a fundamental factor in determining the originality and creativity of the student. But, as showed by de Mello (2015th and 2015b), in the case of a systematic study we must create some very specific rules for the construction of CM, so that they become a kind of algorithmic language.

Conceptual Maps and the Analysis of the Textbook

Due to its concise, hierarchical and graphical way to present the key concepts to be taught we have that CM are a powerful tool to make curricular analysis in general [Novak, 2006; Moreira, 2006]. The hierarchical organization of concepts facilitates the visualization of the optimal sequence of the content presentation both by those who organized them as by the students. And since the fundamental characteristic of meaningful learning is the integration of new knowledge with the concepts and prior propositional structures of the students, proceeding from the more general concepts, more inclusive to the more specific information, we has that the CM serves to foster, promote and assess whether there has been a significant learning [Novak, 2006].

De Mello (2015a) generalized this idea and showed that CM is the natural tool to perform the analysis of the conceptual framework that textbooks books are written. As stated above, due to its concise, hierarchical, graphical way to present the key concepts the construction of an CM for a topic or the whole book, allows you to see promptly and succinctly the conceptual framework that a particular author used to concatenate and organize the key concepts that go into the preparation of your textbook. The simple analysis of a book index or handout not allows us to visualize promptly the underlying structure to the construction of a conceptual body of knowledge. Thus it is necessary to build a CM which show us the interconnection between the concepts inserted and used in each chapter.

Conceptual Maps, Didactic Transposition and Cognitive Models of Science.

As stated above, scientific theories are constructed from scientific models, assumptions and theorems that are propose to explain a certain set of events. These explanations are structured around concepts, nodes or links (Latour, 1999), which allow us to understand the scientific activity. [Izquierdo, 2003].

Thus, being CM diagrams of meanings, indicating hierarchical relationships between concepts or between words to represent concepts, these are the ideal tool to map as these nodes or links are prepared and organized so as to create a coherent whole and that make sense to a certain level of schooling. That is, to study how the knowledge produced to a level of schooling is transcribed to another.

Thus being CM diagrams of meanings, indicating hierarchical relationships between concepts or between words to represent concepts, these are the ideal tool to map out how these nodes or links are arranged and organized in order to create a coherent whole and that makes sense to a certain level of education. That is, to study how the knowledge produced to a level of education is transcribed to another.

We will analyze and classify the processes and the steps that the knowledge produced in the spheres of research suffers when passing from the university environment, epistemosphere, until reaching the environment of middle school, the noosphere. We will investigate how the mathematical and epistemological difficulties filter out certain concepts and favoring other.

De Mello (2015b) did the study of DT of Black Body Radiation theory, showing that the DT of these occurred in a systematic way and in cascade from the research level to the middle school level. It showed, firstly, that in the pass from the research level to the post-graduate level or to the bachelor level the model proposed by Planck was abandoned and replaced by another model that is in line with modern theories. That is, the explanatory model created by Planck, based on the paradigm (Kuhn, 19xx) of Classical Physics was replaced by a model based on the paradigm of quantum mechanics. And lastly it was shown that the DT of this theory for high school came from this new model and not from the original Planck's article.

We will now confirm this hypothesis by analyzing the DT of the Albert Einstein 2nd paper (1905). Using Conceptual Maps (CM) as a tool for the analysis of the cognitive models of science [Izquierdo, 2003] we will show that the didactic transposition of the photoelectric effect (PE) paper for high school is very similar to the basic university course cycle. That is, the DT for middle school occurs from the DT for higher education and not from the research environment, as pointed out as a general rule by Chevallard (1990).

We chose analyze the PE theme for two reasons. Primarily, because this is one of the basic and most discussed topics in high school, and secondly for having been written when the paradigm of classical mechanics ruled absolutely the scientific thinking of the time, without any other competitor. Completing our analysis we will consider how this fact influenced the epistemological construction of Einstein 2nd paper and as the authors of modern books transposes this construction.

Rules for the Preparation of MC

The main purpose of this article is determined in AE paper and into its transcription to textbooks: a) the models; b) the core of the theory; c) the key concepts; d) the methodology and e) the applications of the theory. Especially as these concepts or nodes or links are inserted, deleted, summarized and twisted to make each text a coherent whole.

So, it is used green boxes to identify the models. Blue boxes are used to identify the conclusions or results. In purple the theory. We will put in yellow boxes the applications of the theory. Finally, we put in coral color the generalizations or universalization of the theory.

Albert Einstein Paper (1905) - On a Heuristic Point of View about the Creation and Conversion of Light.

As previously stated [de Mello, 2015b] the Modern Physics is originated as a break with the thought or paradigm (in the sense of Kuhn) of the classic physics and with the electromagnetism (EM) of Maxwell. Thus, in its second paper Einstein (AE) needs to demonstrate that there is a profound difference between physical phenomena called physical optical and the geometrical optics. See the three first line of boxes in its CM, Fig.1. That these two classes of physical phenomena should be studied as physical events governed by laws very distinct. At first we would have to consider the light as particles whose laws are governed by the laws of classical mechanics and in the second case the light should be considered as a wave and governed by the laws of the Maxwell. But, he draws attention to the fact that these phenomena of Optical Physics are temporal average and not instant measures so that this distinction appears only when we interact with the EM radiation. In this way we have a separation between the two classes of physical events classified as optical physics and geometrical optics.

We said earlier that this article is a direct consequence of the work of the Max Planck or Herr Planck, as Albert called Planck. Thus, Einstein needs to demonstrate that the model of Planck [1901], based in obtaining an expression for the entropy of radiation in the cavity of a blackbody, is a universal model. See the boxes in green in the CM. That is, it is not just a mathematical device, and that this can be generalized for any type of interaction between radiation and the matter.

We see in the CM of his article, that this begins by stating that there is a fundamental difference between the kinetic theory of gases and the Maxwell EM. These theories represent two very distinct physical models and irreconcilable. That EM energy is distributed discontinuously in space. Then, to justify this 'apparent' dichotomy he affirms that the phenomena of optic physics are temporal average and not instant measures. In this way we have, for the first time, a separation between the two classes of physical events classified as optical physics and geometrical optics. With this he justifies the construction of a model of particles to explain the physical phenomena called geometrical optics and which cannot be applied to radiation in general. We see then in this CM, fig.1, that as observed by the theoreticians of the 'theory of Cognitive Science' [Nesserssian, 1992], that by similarity Einstein will generalize the theory of Planck (1901) to generate a model of particles to explain the phenomena of the interaction of radiation with the matter. Thus, in Chapter 1 he begins by constructing the model for the radiation in the cavity of a black body (BB) as being produced by oscillation of electrons in the walls of that cavity. Boxes in green. Using the model of the kinetic theory of gases he rescues the equation to the density of radiation of Planck and shows that the energy obtained by the sum of the power density for all frequencies would be infinite. This implies the non-existence of Ether. Notice that this is very important in the construction of the particle model. Therefore, the existence of ether implies the existence of a material means to the propagation of EM waves. This is, would imply that the Light or EM radiation should be a wave.

Note that the non-existence of Ether in the history of science is associated with the theory of relativity, especially to the experiment of Michelson and Morley, not to the postulate of wave-particle duality. This is due to the fact that in general the major 'breakthroughs' of physics are associated with experimental facts and not with models or assumptions. Maybe that's responsible for the fact that the epistemological importance of physical models in the construction of Physical theories has stayed in the background until now.

In chapter 2, it shows that the Planck equation obtained in the low frequency limit, using the assumption g that energy is quantized in Black Body (BB) cavity, falls within the Maxwell EM radiation model, or the continuous spectrum model, sees fig.1. As Einstein said in his other Article [1905b], a new theory must explain the previous theory within its limits of validity.

In chapter 3 Einstein shows that the BB Radiation Law can be obtained directly from the application of variational principle to entropy function for radiation within the cavity, universalizing this model. see fig.1.

In Chapter 4 he demonstrates that the formula of Wien is equivalent to a model of ideal gas for the radiation, given by the Boltzmann's equation for the entropy. Thus, he concludes the model.

In Chapter 5 he proves that the Theory of Boltzmann is universal, legitimizing its entire epistemological construction, see box in coral color in fig.1. We see here that in this article Einstein not only generalizes the ideas of Planck for the quantization of radiation of BB, but he also universalizes the Boltzmann model. Here we have the genesis of statistical mechanics.

In Chapter 6 he shows that, for low densities of energy, the application of the theory of Boltzmann to the radiation of the cavity of BB implies that the energy in the cavity is quantized - The Theory. Box in purple. This energy is given by

$$E = R\beta v/N$$

Where β is the Boltzmann Constant, v is the frequency of light and R is the ideal gas constant, see fig.1. This equation is better known by the equation E = H. v, where h is the constant of Planck.

As the own Einstein said, a new theory must explain experimental facts that the old theory cannot explain. As we said earlier, Hesse (1963) states that scientific models allow a theory to be predictive. Thus, in the sequel he will apply their model of particle for EM radiation to explain the Stokes rule for the phenomenon of emission and absorption of the fluorescent rays, Chapter 7. In Chapter 8 he will apply the model to explain the photoelectric phenomenon, and in the ninth to explain the phenomenon of ionization of gases by ultraviolet rays. See boxes in yellow in Fig.1.

Finally, in Chapter 8 he applies his theory to explain the photoelectric phenomenon. For this reason he builds a model for interaction of the radiation with the matter, where he applies his quantization of radiation hypothesis. Box rectangular in yellow. From this model and the conservation of energy he obtains the linear dependence between the kinetic energy of the ejected electrons with the radiation frequency of the incident light. This explains the experimental data obtained by Lennard.

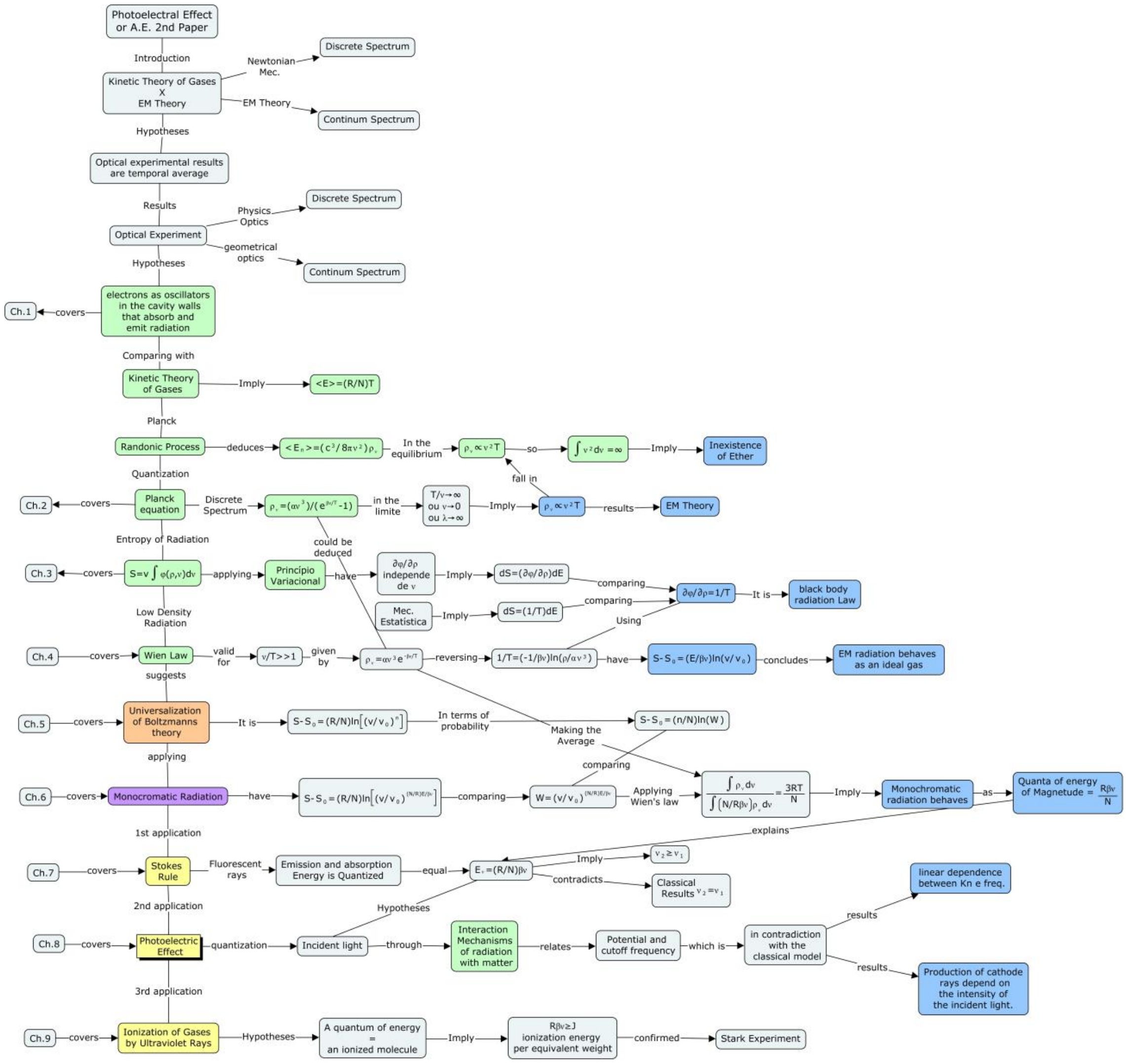

Fig.1 - CM from the original article "Albert Einstein 2nd paper"

2 - Quantum Physics - Eisberg and Resnick (1985)

Let us see below as this epistemological construction was transposed in general to the text books. We will use the textbook 'quantum physics' of the Eisberg and Resnick authors as textbook default prepared for the bachelor level of education to the Physics course.

We did the CM, fig.2, for the section that deals with the theory of the photoelectric effect. The structure of their modern physics texts is something like this: a) present the experimental results and the fact that they contradict the classical theories, gray boxes in the CM, fig.2; b) then the theory, purple boxes; c) finally applications (boxes in blue) and when there are generalizations or universalizations (boxes in coral). And in the case of the PE the scientific model was developed in the previous section, BBR, so it do not appear in the text.

We can see in their CM that to make the didactic transposition of the theory of the photoelectric effect the authors claim that Einstein generalized Planck's hypothesis of energy quantization. But they say nothing about it was Einstein who universalized

Planck's theory, and deduced an expression to the Planck constant (h) by defining a function for entropy according to the Boltzmann and from ideal gases constant. Purple boxes. As in many other examples of didactic transposition, certain constants earn name and own importance. For example, the Young's modulus. We believe that due to the definition of a function for the entropy be unnecessary for the explanation of the EF, the relationship between Planck's constant and Boltzmann constant be omitted in all textbooks.

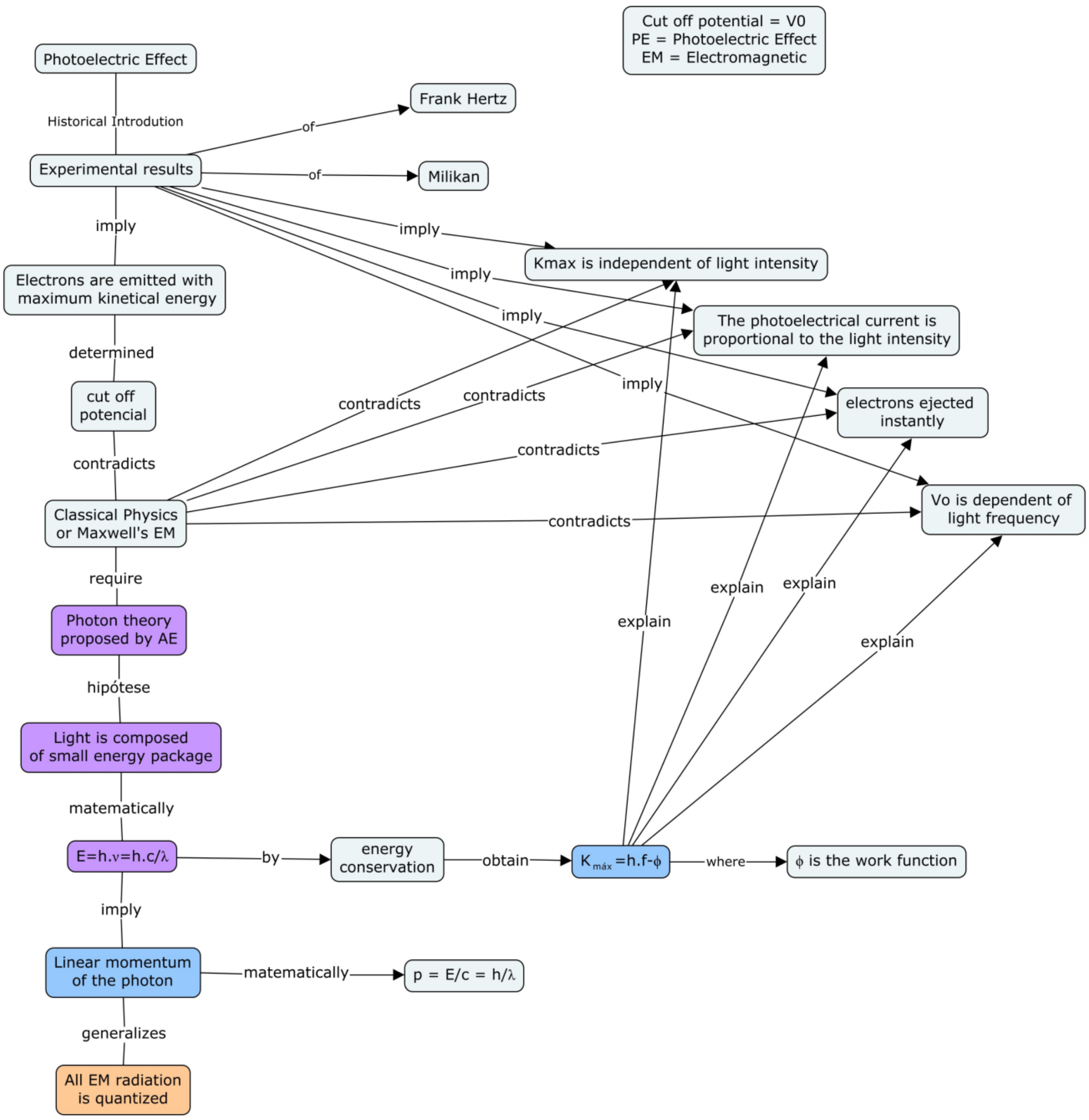

Fig.2 - CM from the PE topic of the book Eisberg & Resnick

Part of the ideas developed by Einstein in his article is used in the development of the chapter on BB radiation, but without any citation to this. See Reference [de Mello, 2015]. Here we see that there is no citation that this model implies the absence of ether, not even in the chapter on the BB theory of radiation.

Here we see as the first version of this book was written at the end of the 1960s and beginning of the 1970s, where the Quantum Mechanics was already accepted 'universally' as Physics theory, that all the conceptual development that Einstein did to show that for low frequencies the Boltzmann theory applied to BB radiation falls on Maxwell's theory for the EM radiation, was deleted from the development of this section and the book. See purple boxes in Fig.2. Also, there is no citation that was in this article that the theory of Boltzmann won the character of universal theory, since at this time the statistical mechanics already had the status of theory and in many universities was considered one of the physics course discipline. They briefly comment the corpuscular model created by Einstein to explain the dual behavior of EM radiation to mention that 'Experimental measures are time averages involving a very large number of photons'. Omitted in the CM.

We see in the first box of your CM and in its connections, fig.2, that the whole basis of the theory of the photoelectric effect of EA is in the detailed description of the experimental facts obtained by Lennard and on the fact that the classic model, based on the theory of Maxwell, is not in accordance with these facts. Firsts grey boxes. As the theorists of Cognitive Theory of Sciences say: AE's theory is a theoretical model constructed to explain the EF on the basis of similarity with the experimental data available for a given physical phenomenon. We can also see that the book of Eisberg is a book written to train scientists, that is, always presents firstly the experimental facts and only after the theory that explains. For this reason they anticipate the experimental data, or linear dependence between the frequency of light and the cutting potential. (Millikam)

By comparing the CM from AE 2nd paper and the chapter of Eisberg, and bearing in mind (according to the CTS) that the physical model is only a mental construction to make a predictive theory [Hesse,1963], it is observed that what is theory to the phenomenon of photoelectric effect, that is, what does not change with the evolution of science, are the hypotheses: 1) a photon is absorbed completely and instantly by a single electron; 2) by conservation of energy the electron ejected with greater energy will have kinetic energy equal to the difference between the energy of the absorbed photon (H.ν) and the function work V_0. That is, the equation

$$E_k = H.\nu - V_0 \ \text{(Joule)}$$

Along with the 1st hypothesis explain all experimental facts, without the need for any model.

- Books Written to the Basic Cycle

3 - The Physical Principles of Authors Serway & Jewett [Serway & Jewett, 2006].

As example of Modern Physics (FM) text writing to exact science course and that follows almost the same structure of Eisberg we have the book Principles of Physics of authors Serway & Jewett [Serway & Jewett]. We have in figure 3 its CM. These present the experimental results and the fact that these contradict the classical theories; the 1st boxes in gray. Then they expose the model, green boxes. In sequence the theory, purple boxes; and finally applications (boxes in blue).

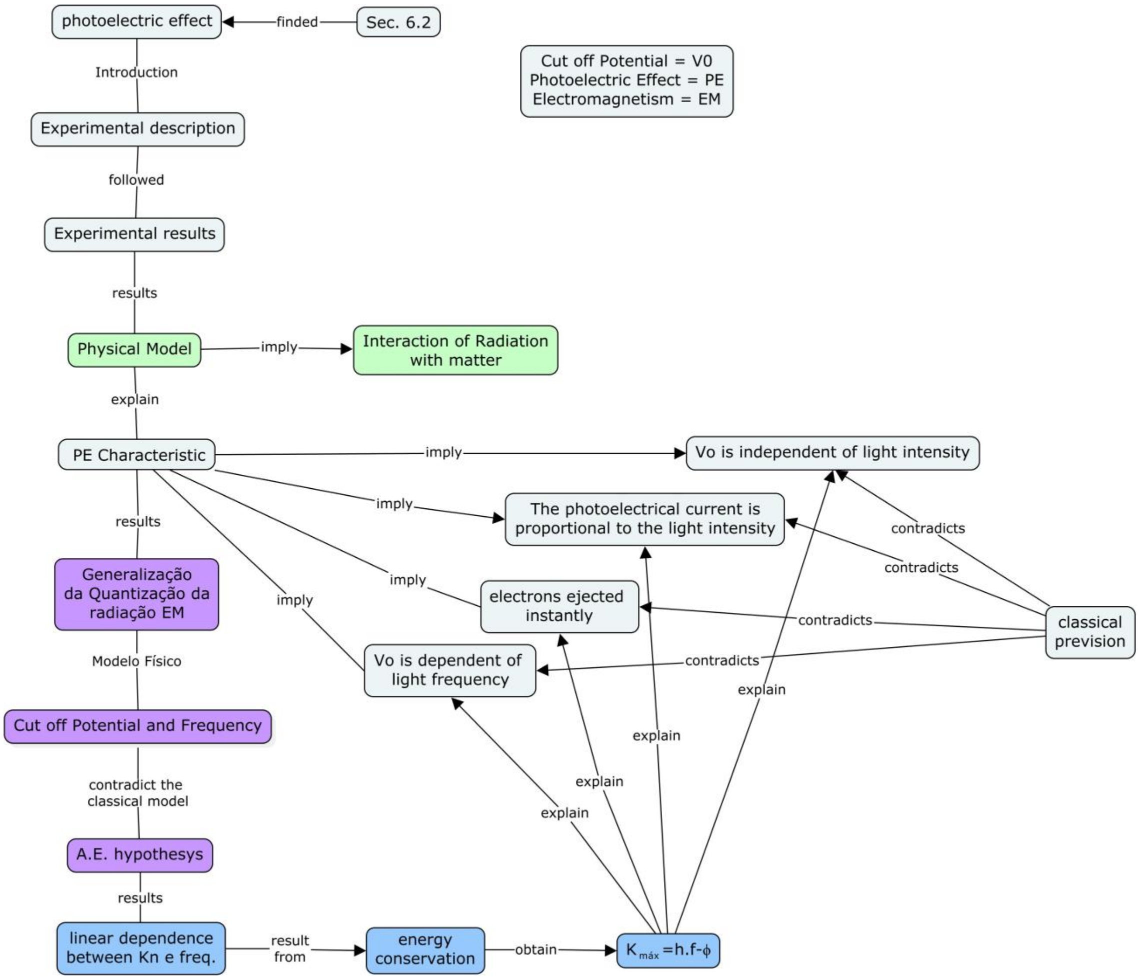

Fig.3 - CM from the topic of the book EF Serway & Jewett

By comparing the CM of Serway book with those of AE 2nd paper and with the book of Eisberg we observed that the DT for the PE is made from the text of Eisberg and not from the original Einstein paper. With the exception of the order of presentation of some topics they address the same concepts. Basically the great difference between them is in the greater emphasis given by authors Eisberg and Resnick in the review and description of the experiment and in the experimental data that have led to the formulation of the theory of PE. For this reason they anticipate the experimental data, or linear dependence between the frequency of light and cutting potential. They comment briefly the corpuscular model created by Einstein to explain the dual behavior of EM radiation by noting that "Experimental measurements are time averages involving a large number of photons'. Omitted in the CM.

These also omit a) the fact that it was Einstein who universalized Planck's theory, b) and deduced the expression of Planck's constant h as a function of Boltzmann constant, by defining a function for entropy from a model of ideal gases. Nor does any citation that this model implies the absence of ether. Not even in the chapter on the theory of radiation of BB. Neither cites the conceptual development that Einstein done to show that for low frequencies the theory of Boltzmann applied to radiation of BB lies in the theory of Maxwell. See Fig.3. Also there is no citation that was in this article that the theory of Boltzmann won the character of universal theory.

4 - Physical IV; 'Optics and Modern Physics' of the Authors Young & Freedman (2008).

The second book chosen is of the authors Young and Freedman. As discussed in another article [de Mello, 2015a] it chose this book for having a very different structure of the Eisberg book. See de Mello (2014). Due to the very particular characteristics of the theory of the photoelectric effect this topic is very similar to the other texts. Due to this text presupposes that the students (reader) already know what the PE is, they change the order of presentation of the model with experimental facts. So, they begin this section by defining what is PE through the model of interaction of the radiation with the matter, and exposes in sequence the experimental facts. See the green box in Fig.4. After, the text does not differ in almost nothing from the Eisberg. In sequence they present the experimental results and the fact that they contradict the classical theories, gray boxes in the CM, fig.4. Then, they expose the theory, purple boxes, its applications (boxes in blue) and the generalization or universalization (boxes in coral) that all EM radiation is quantized. And they finalize this section with the relativistic definition of momentum of a photon due to the fact that they need this later. They, like all texts for university basic cycle, do the same omissions that the above texts.

- Book Written for the Middle School

5 - Physics Principles and Problems - Glencoe Program (2005).

This book (Glencoe) was chosen because it is a very used text in middle school of United States of America and its use the “based learning problem” as learning methodology. This topic, like many others, does not use any scientific explanatory model to illustrate the theory. As the text of blackbody radiation, they introduce the topic through an experimental puzzle, green lemon box:

> *When ultraviolet radiation was incident on a negatively charged zinc plate, the plate discharged. When ordinary visible light was incident on the same charged plate, the plate did not discharge. This result was contrary to electromagnetic theory.*

Then they make a detailed experimental description of PE. The main PE characteristics they stress are: (a) cutoff potential energy and b) instant emission of electrons. Then they argue that these facts cannot be explained by classical EM theory. And involving the assumption that light is composed of quantum of energy and introduce the concept of photon, see figure 5.

Note that they do not expose the PE model. They go directly to the theory. See boxes purple. But they draw attention to the fact that AE generalized the Max Planck concept of quantization of energy for all types of EM radiation. See box in coral.

Then they expose as the theory of PE of AE explains the phenomenon of cutoff potential, see CM in fig. 5. They complete the chapter by testing the theory of EF through some of its applications. See blue boxes, fig. 5. They shall finalize the theory by defining the cutoff potential energy through the Millikam experiment. See purple boxes, fig.5.

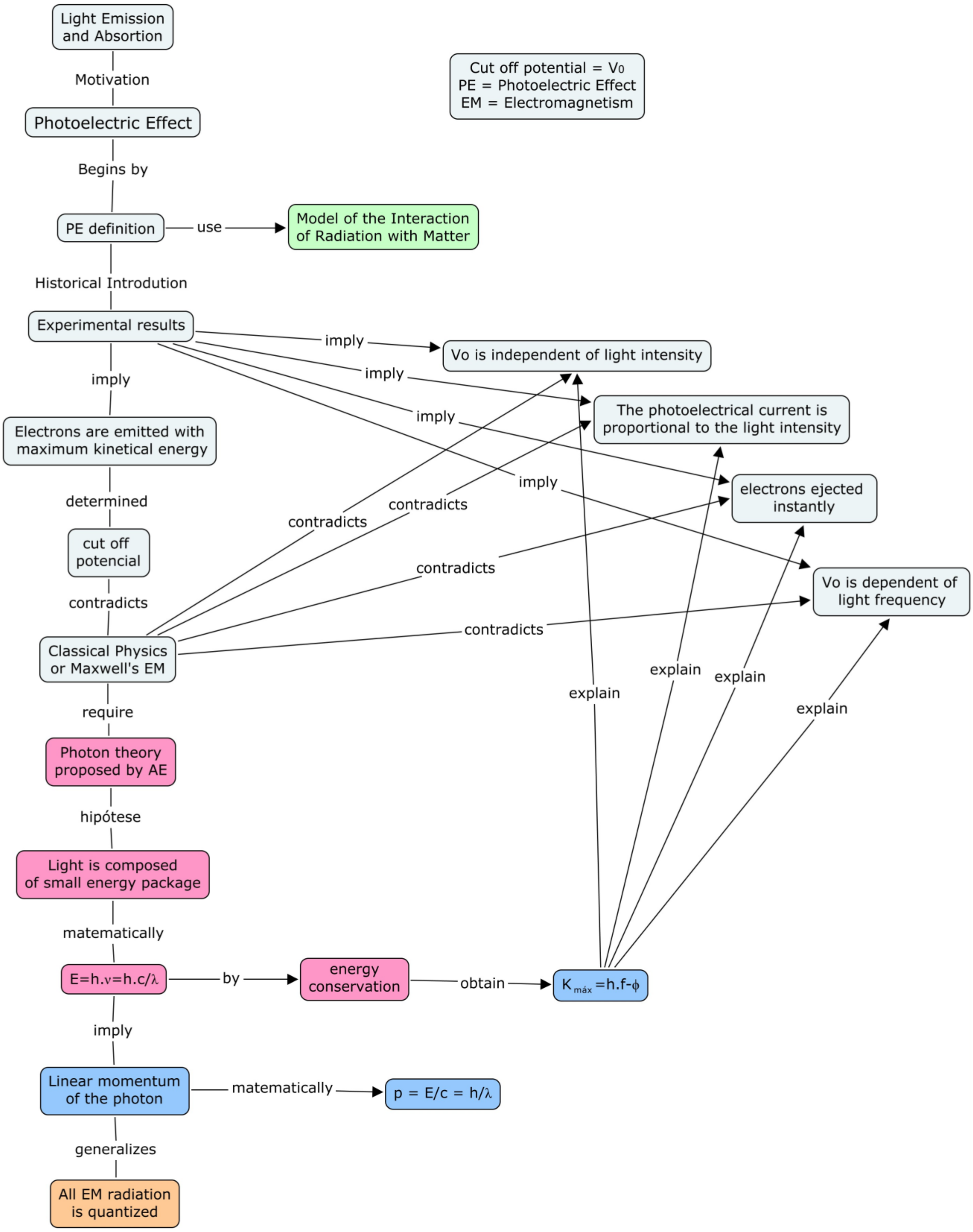

Fig.4 - CM from the topic of the book EF Young & Freedman

Thus, this book is a DT of the books written for higher education and not from scientific articles, as the other books written for the middle school. See Fig. 5. These also omit the fact that it was Einstein who universalized Planck's theory. That deduced the expression of the constant Planck in function of Boltzmann Constant through the definition of a function for the entropy for ideals gases. Nor does any reference that this model implies in the absence of ether. Not even in the chapter on the theory of BB radiation. Neither cites the conceptual development that Einstein done to show that for low frequencies the theory of Boltzmann applied to BB radiation lies in the theory of Maxwell to the EM radiation. See Fig.5. Also there is no citation that was in this article that the theory of Boltzmann won the character of universal theory.

Note that the PE physical model is diluted in the text, which shows us that the authors give much more importance to physical phenomenon than to their explanatory model. Confirming that the physical model is part of the theory explanation and is not the theory itself, as stated by the CTS.

Discussion and Conclusions

It has been shown here that CM is the natural and most effective tool for making an analysis of how the concepts, propositions, theorems and explanatory models are used to construct a certain theory, as well as to make the study of how this is transcribed didactically. Through the analysis of how the theory of PE developed by Einstein on his 2nd article was transposed to the textbooks, it was shown that CM is a tool, an algorithmic language, very efficient and succinct to present and describe as an original conceptual framework is implemented didactically in different types of textbooks. It was shown that for an expert in cognitive science theory the simple study of CM, designed for a given theory and done within certain strict rules, is sufficient to understand its conceptual framework. It could be seen as each author has organized and merge concepts (nodes or links) to form a coherent whole.

Through this study it was possible demonstrate that we present to the students, making a DT, some reconstructed facts, theoretical models, arguments and propositions that were previously selected. We show again [de Mello, 2015b] that in most cases the theoretical models, or scientific models, are adjusted and/or modified for the level of understanding of the students. And over time these models will be perpetuated so that teachers teach the DT science as this was the truth.

Showed again that the DT not occur entirely within the classroom or in the "professor's office." By making CM to texts written to train scientists, to train engineers and other written with well defined teaching methodologies (Glencoe), we observed that the DT for the PE is strongly influenced by this fact. That is, currently the DT of a given scientific knowledge is carried out in the university or epistemosphere and not directly to the high school. And this is done within standards set by the teaching methodology employed.

It follows that, for educational purposes, scientific models are no longer the centerpiece in the development of a given theory. It is noted here that in Eisberg and in the Jewett texts the experimental facts stand out the model. In the text of the Sears stronger focus is given to the model of interaction of radiation with matter than to the experimental facts. In the Glencoe text is given greater importance to the problem of understanding the experimental facts, the problem or project, secondly to its technological applications and briefly explains the model of interaction of radiation with matter.

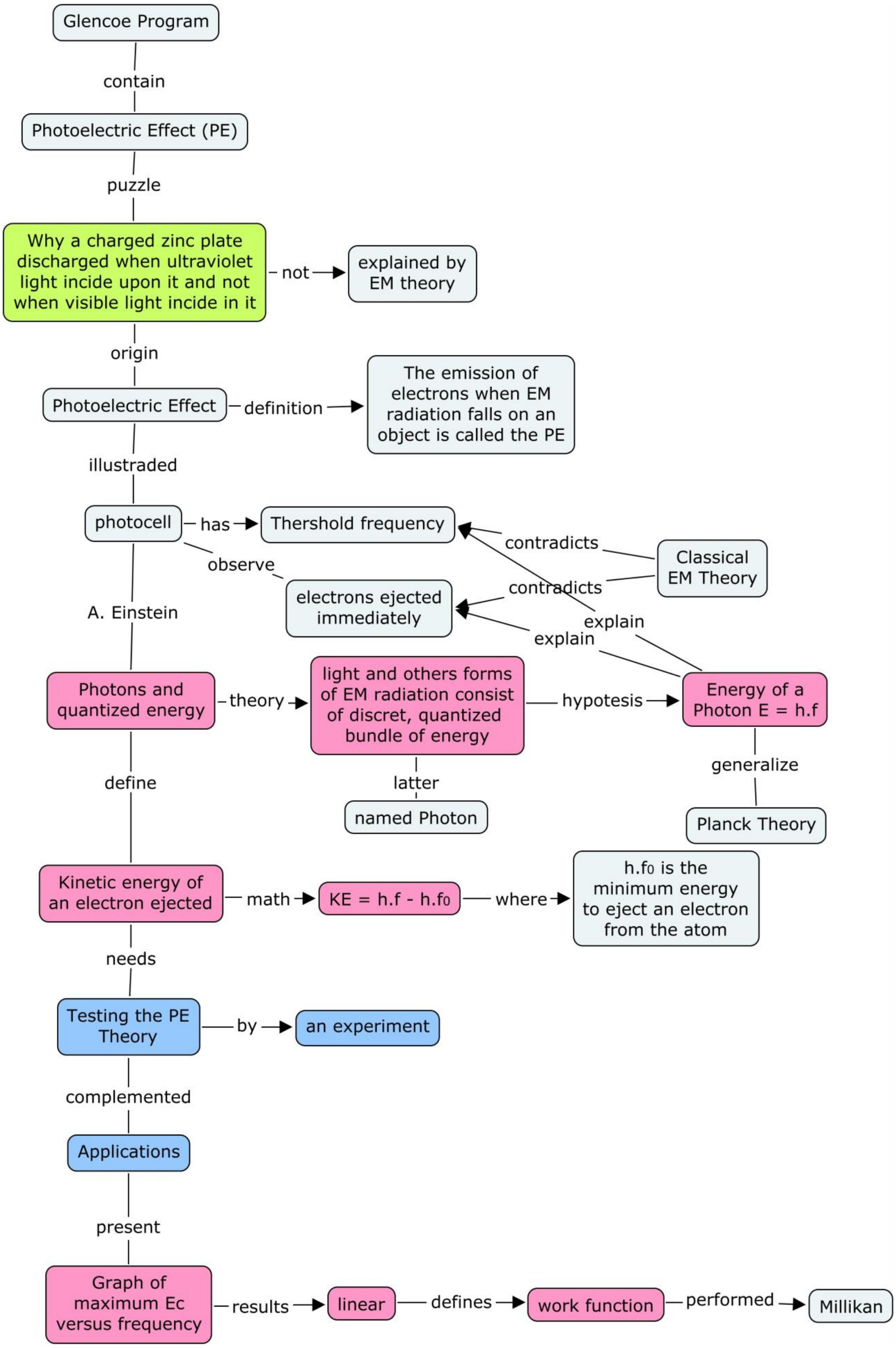

Fig.5 - CM from the topic of the book EF Glencoe

It is demonstrated here the thesis of Latour (1999): what school science and the science of the scientists have in common is that their ideas, their theoretical concepts, were arrested and sealed inside of black boxes after having gained importance and after they become more "solid" and "strong". That is, after " consolidated". Izquierdo (2003) proposes, as demonstrated here to the case of PE and in de Mello (2015b) for the theory of BB radiation, that such packaging process leaves out details, explanations and reasons which before were necessary to convince others of its "original power explain" (both to the scientific as to the didactic level).

Izquierdo-Aymerich and Aduriz Bravo (2003) argue that what we know about the model as a didactic concept, how and where it appears in the curriculum, why and how he transforms, etc., is also limited, because we really do not know much about his "history" as a didactic element both in chemistry and in physics teaching. But, if we limit the study to the conceptual framework of a certain theory, we can create rules using CM [de Mello, 2015] to see how they were being transcribed, suffering a DT, to acquire the presentation form of the bachelor level. From this to the basic cycle and from this to high school.

Moreover, it is possible that teachers think: a) that a given theory (e.g. PE) has always been present in textbooks; b) that reflect not only the true scientific knowledge, but as this "is" really done. This results that they end up giving more weight to the value to the truth of the model than to the theory (Izquierdo-Aymerich, Aduriz and Bravo, 2003). Due to its relative ease of suffering a DT, as for example: capacity to generate problems and/or mathematic simplicity, makes certain concepts such as the atomic model, the PE, the BB radiation, so powerful within the science of school narrative.

Thus, currently, to make a didactic transposition the professional in the teaching of sciences must have in mind what are the scientific models involved in the construction of a certain conceptual theory, its relevance in the theory and the impacts on these if this model is modified, simplified and/or deleted. That is, a specialist in DT must be able to define the changes that the scientific model must suffer and which metaphorical models may dispose, so as to make a proper DT for a given level of understanding, without sacrificing the veracity of the concepts involved. And to ensure a meaningful learning (Ausubel, 1977) the educator must have in mind what would be the alternative concepts of the learners and how to make the bridge to the scientific concepts.

Acknowledgements

Thanks to the national professional master's program in teaching Physics (MNPEF) which gave us the opportunity to conduct such studies. To CAPES for promoting this research. And the lecture of Prof. Mario J. de Oliveira (2006) explained the crucial points of development of the theory of blackbody radiation.

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